ARTEMIS INTERNAL SCIENCE TEAM UPDATE: DATA AND SOFTWARE DEVELOPMENT. M. J. Miller[1], N. E. Petro[3], S. J. Lawrence[2], the Artemis Internal Science Team. [1]Jacobs, NASA/JSC, Houston, TX 77058 (*matthew.j.miller-1@nasa.gov*), [2]NASA/JSC, [3]NASA/GSFC.

Introduction: Artemis will reestablish human presence on the Moon and lead to a new era of scientific discovery and exploration. Led by the National Aeronautics and Space Administration (NASA), Artemis includes a collaboration of space agencies and companies from around the world [1]. In support of Artemis, a cross-disciplinary effort of science, engineering, mission operations, and human factors personnel is developing the best methods, facilities, and field locations to test hardware, train astronauts, and evaluate modern concepts of operations. This abstract, as part of the Artemis Internal Science Team (AIST) [2], provides an update to the science-relevant *data* and *software* developments and integrated testing efforts that have occurred in 2022.

Geospatial Data Management: The recent flood of data from orbital missions fundamentally enables Artemis exploration of the lunar surface. However, for every valuable map product are multiple early-iterations of such products. A guiding principle of the Artemis Geospatial Data Team (see [3, 4] for more details) is to define and create map products of sufficient quality as to be useful for site selection, mission planning, and EVA implementation purposes via dedicated software tools. Some key accomplishments of data development include the consolidation of agency skillsets into a newly formed Artemis Geospatial Data team as led by AIST Spatial Planning and Data Lead (Petro) and the AIST Mission Planning Lead (Lawrence), the formal documentation of Artemis lunar data, and infrastructure development surrounding the production, hosting, and sharing of geospatial data products for NASA and collaborators.

The Lunar Surface Data Book [5] baseline draft (ACD-50044) was created in 2022 and provides a common reference set of existing lunar surface data, products, analytical assumptions, and representative use cases to be incorporated into Artemis surface mission planning efforts. This document pertains solely to the surface of the Moon and the ecosystem of data and products to be used to describe the lunar surface. Updates will be made in this document as warranted by new data products and improvements to existing data products in the coming years. This document in particular augments the Cross-Program Design Specification for Natural Environments (DSNE) documentation [6] for a consolidated view of the data products that presently exist to inform Artemis mission development

The Artemis Geospatial Data Team was established in 2022 to coalesce agency-wide geospatial data creation and analysis skillsets to meet the growing demand for lunar surface map products and analyses. This team is comprised of personnel that span many NASA directorates and centers. See [3, 4] for a more detailed discussion of the types of problems and products this team is currently addressing. Of particular importance at present is the Artemis III site selection process and ensuring decision-makers have the highest-resolution and most scientifically valid lunar surface data products and analysis results [4].

Geospatial Data Handling: Alongside a dedicated team of experts addressing geospatial data problems is an effort to establish a streamlined geospatial data management system to host, curate, and distribute Artemis data. Server hardware and infrastructure is under active development to ensure the geospatial products necessary for Artemis can be controlled for quality, accuracy, and availability to all relevant parties. In doing so, this capability will ensure the correct data can reach the correct Artemis members to inform mission development.

Software Development: Artemis missions will involve a host of modern software expectations regarding data access, manipulation, and viewing to support mission operations, none more so than during lunar surface extravehicular activity (EVA) operations. Therefore, the need to seamlessly integrate geospatial and temporal data sets into meaningful flight products is paramount [7]. In doing so, mission constraints and expectations can be aligned with scientific objectives to ensure the Artemis campaign can capitalize on every opportunity afforded during each lunar surface mission while maintaining crew and vehicle safety.

The AIST Software Systems Lead (Miller) is coordinating the development of EVA Mission System Software (EMSS) within the formulation of the Artemis EVA flight operations team [8] in conjunction with the geospatial data product development efforts previously discussed. The EMSS initiative is developing three software tools to support Artemis EVA operations: 1) an EVA procedure authoring and execution tool (known as *Maestro*), 2) a lunar surface EVA planning and execution tool that unites the EVA mission data with geospatial map data (known as *Artemis EVA Geographic Information System, AEGIS*), and 3) a mission context creation tool (known as *Collaborative Operations Data Activation, CODA*) that enables any mission, training, and test event to be relived and analyzed across each moment in time, both within a mission and post-mission during analysis.

The EMSS initiative had major accomplishments in 2022 that we highlight here to the broader scientific community to explain the progress being made towards building these tools now so that they are ready to support Artemis missions.

Maestro was successfully deployed in the planning, training, and execution processes of International Space Station (ISS) EVA in Nov and Dec 2022—the first time in EVA history a *digital* EVA procedure was authored and executed. Maestro enabled the first MCC-wide EVA procedure flight-following capability for hundreds of flight controllers to track EVA progress, while reducing extraneous communications on the flight loops.

CODA experienced dramatic user adoption in the past year. The CODA team was awarded the 'Major Space Act' award by NASA for enabling the instant and consolidated review of over 13 years' worth of ISS data. CODA is a major leap forward because it moves away from the concept of the individual data file and allows users to move fluidly through an event during an EVA using multiple data sources. In doing so, users can see contemporaneous data to better understand events (e.g., EVAs) and reconstruct lessons learned during missions, training, and test events. The platform has been extended to include other facilities such as the Neutral Buoyancy Lab (NBL), EVA field testing events [8], and the Artemis I mission. On-going work consists of gaining access to additional data streams (system telemetry, orbital trajectories, transcripts, etc.) from these facilities and thereby enabling more mission context to be consumed and reviewed by the operations community.

AEGIS saw significant growth and utility as a concept in 2022. The AEGIS team was instrumental in the EVA product development and work instruction process for JETT testing efforts [8,9] which marked the most realistic Artemis lunar surface EVA planning and execution processes performed to-date since Apollo. As of Jan 2023, only commercial and open-source GIS software tools were available for EVA operations. However, these tools lack the mission specific capabilities to enable EVA operators to plan, train, and fly lunar surface operations. AEGIS has successfully transitioned from concept or proof-of-concept phase (e.g., learning from readily available mapping solutions) to a dedicated design, prototype, deploy strategy. In doing so, AEGIS helps coordinate and keep the flight and development teams in sync with the underlying desired workflows currently under development. This also ensures that AEGIS, which is now under active development, meets the needs of EVA operators.

AEGIS, alongside CODA and Maestro, will undergo iterative improvement in the coming years as workflows and mission demands become more refined so that these tools directly support the work demands of the flight team (which includes operations and science personnel) charged with planning, training, and executing Artemis EVAs.

Mission Development and Integrated Testing: Enabling the scientific enterprise within Artemis starts with enabling mission members to work with the best scientific understanding of the lunar surface. This is done by not only serving the underlying scientific data, but also serving it in software tools that seamlessly align with mission planners and operations job duties. The AIST data and software team is making tangible progress towards realizing this aim. NASA has consolidated the geospatial activities for Artemis within NASA into the CASSA framework [4], , focused our unified effort into governing program documents such as ACD-50044 and applying our efforts on pressing agency program needs, started the creation of a quality controlled and shareable repository of lunar geospatial data, and established an integrated software development team to create mission system support tools for the EVA flight operations group.

Additionally, these development activities are pursued in the context of the integrated EVA testing and field training as discussed by our colleagues Young [9], Graff [10], Evans [11] so that our data, processes, and software functionality meet Artemis mission demands.

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References:

[1] Artemis Lunar Exploration Plan (2020). [2] LPSC (2021) Artemis Town Hall. [3] Petro, N. et al., (2023), *these proceedings, Abst.* [4] Lawrence, S. J., et al. (2023) these proceedings [5] NASA (2022) https://ntrs.nasa.gov/citations/20220015275 [6] NASA (2019) https://ntrs.nasa.gov/citations/20200000867 [7] Marquez & Miller, (2019) DOI:10.1089/ast.2018.1838 [8] Caswell T. E. et al. (2023), *these proceedings, Abst.* [9] Young K. E. et al. LPSC (2023), *these proceedings, Abst.* [10] Graff T. G. et al. LPSC (2023), *these proceedings, Abst.*[11] Evans C. et al. LPSC (2023), *these proceedings, Abst.*